Handwriting Slant Correction using 8-directional Chain Code Method

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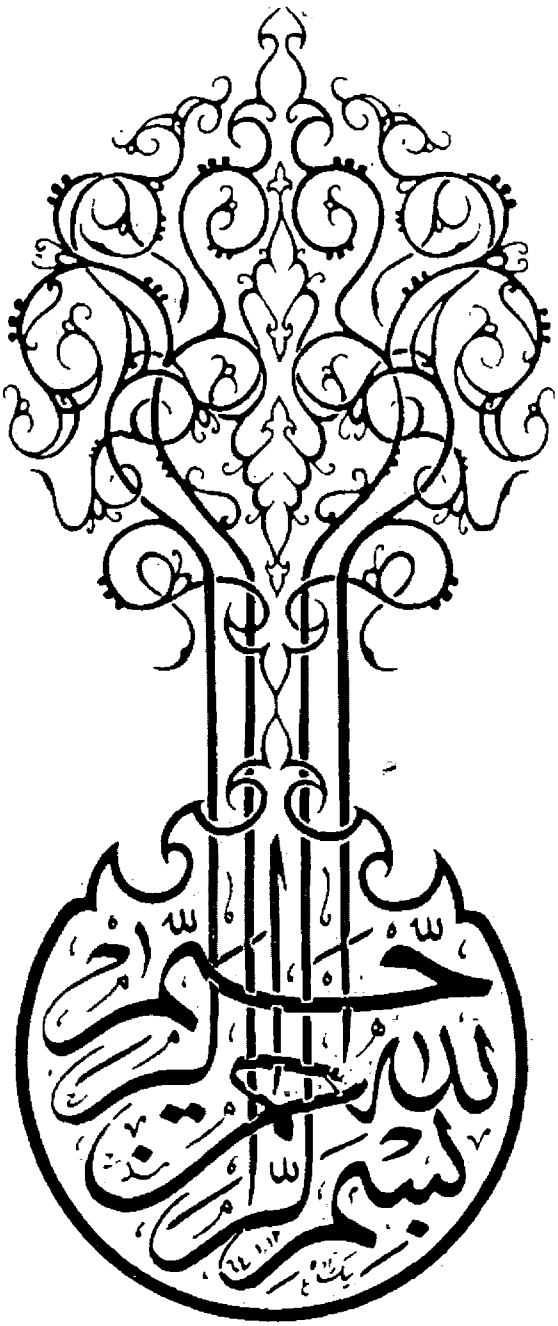
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I declare that this research work entirely based on my personal efforts under the supervision of Dr. Muhammad Faisal Zafar. It is further certifying that except where due an acknowledgment has been made, this research work has not been copied from any source: the work has not been submitted previously, to qualify for any other academic award.

Zia ur Rehman

114–FET/MSEE/F07

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Abstract

Slant correction is a fundamental preprocessing step in handwritten word recognition system. Accurate slant estimation and correction creates simplicity in segmentation. It also escalates handwritten word recognition accuracy. So many algorithms have been proposed by researchers; however there is still a lot of space for improvement. This research work presents enhanced technique for slant correction using 8-directional chain code method. This research aims to propose/modify an efficient and simple slant correction technique so that better results can be obtained in script word recognition system. The factors close to horizontal lines are neglected to increase the accuracy of 8-directional chain code method. This method slightly enhanced the slant correction accuracy of 8-directional chain method. In addition to this, it also concentrates in order to avoid computational difficulties and heuristics implicated in the slant correction techniques. In addition to this, the relationship between different directions like 4-direction, 8-direction and 12-direction are also discussed. Moreover, a comparative analysis of chain code with regression, structural features and histogram based slant correction techniques are also presented in this work. A number of experiments were performed on words images database to analysis and compare different slant correction approaches of handwritten words images. The experimental result of proposed technique is promising and satisfactory.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS

CSWR	Script Words Recognition System
PPT	Projection Profile Technique
CCT	Chain Code Technique
ZMT	Zernike Moments Technique
PMT	Propagation Map Technique
RTT	Radon Transforms Technique
NUT	Non Uniform Techniques
CFT	Cost Function Technique
8-DCCT	8- Directional Chain Code Technique
M. 8-DCCT	Modified 8- Directional Chain Code Technique
HBT	Histogram based Technique
RBT	Regression based Technique
SBT	Structural Features based Technique

CHAPTER 1

INTRODUCTION

The script words recognition system (SWRS) is ordinarily described by slanted letters. A slanted letter in English word images usually seem positive or negative direction but have the supremacy of positive direction. It is challenging to distinguish the characters properly due to the enormous inconsistency of handwritten characters. The handwritten characters have to be treated to sort it appropriate for recognition by applying preprocessing steps like noise reduction, skew correction and slant correction. Handwritten words are customarily slanted in line with nature and habit of a writer. Slant correction plays a vital role in script word recognition system (SWRS). It simplifies onward steps like segmentation and recognition.

The authors [6, 7, 8, 9, 10] proposed slant correction and estimation techniques based on chain code method. Analysis of different techniques discloses that the slant of a word modestly and accurately estimated by chain code techniques. The information obtained by direction feature is

based on the identification of individual segments. It extricates each segment in terms of its regularized directions.

1.1 Problem Statement

It is recognized that, slant has a harmful influence on recognition and segmentation stages in SWRS. These stages are substantial part in recognition process. Besides this, it is potential to enhanced recognition stage accuracy in SWRS if the slant in character, words or text is accurately detected and removed.

1.2 Objectives

This research aims to propose/modify an efficient and simple slant correction technique so that better results can be obtained in script word recognition system. In addition to this, it also concentrates in order to avoid computational difficulties and heuristics implicated in the slant correction techniques. Moreover this research also provides comparison between different slant corrections techniques used in the literature.

1.3 Methodology

In this research work author proposed an enhancement in 8-directional chain code technique (DCCT) for slant correction of a word image. The technique detects the slant of handwritten words and then eliminates the slant from a handwritten word image. In order to compare the accuracy of 8-DCCT, slant by 4- DCCT and 12-DCCT are also presented. This research work also concentrates on the comparative analysis of slant correction by chain code method with histogram based technique, regression based technique and structural feature based technique.

To evaluate the accuracy and comparative analysis of different approaches, a number of experiments have been carried out. The data used in these experiments was taken from renowned handwritten database: IAM-DB. Results of these experiments are up to the mark.

1.4 Organization of the Thesis

The rest of this research work is split into following chapters:

Chapter 2: Handwriting Slant Overview: Literature survey and basic concepts of handwriting slant is discussed in this chapter. Problem in slant estimation and application of slant correction are also presented in this section.

Chapter 3: Slant Detection and Correction Techniques: This chapter deals with the approaches described in the literature to detect handwriting slant. It also entitles the merits and demerits of different slant estimation and correction approaches.

Chapter 4: Simulation Results: Simulation results along with brief description of different techniques are offered in this section. In addition to this, comparative analysis of different techniques also remains under discussion in this chapter.

Chapter 5: Conclusion and Future Research: The last chapter is about the summary of different techniques and their assessment. Furthermore, future research work is also explained in this section.

CHAPTER 2

HANDWRITTING SLANT OVERVIEW

Handwriting recognition is a process in which spatial form of script is transferred to its symbolic form [1]. Handwriting recognition has been under study by several castigations for different purpose and from different aspects encompassing office automation, transcription of documents, postal sorting, bank-cheque and in the field of legal problems and criminal investigations. Analysis of hand writing recognition, interpretation and verification is the major prospect in the field of computer science [2].

2.1 Overview of Handwriting Recognition

The handwriting recognition process is generally divided into two main domains [10]:-

- Off-line handwriting recognition process
- On-line handwriting recognition process

2.1.1 Off-line Handwriting Recognition Process

In this process, handwriting is sampled, digitalized and processed after it has been written [10]. The data obtained by this method is regarded as static representation of handwriting. The information about pen directions and speed of writing are not available in this method. Different handwriting styles make off-line handwriting recognition process difficult.

2.1.2 On-line Handwriting Recognition Process

On-line handwriting recognition is a process in which the handwriting is sampled, digitalized and processed in real-time as it is written [10]. The system requires a device to produce digitalized coordinates of the pen strokes. Generally the result of on-line recognition process is obtained instantly after completion of the recognition of a character, symbol or word. However, in some cases, the result may be processed later [15].

2.2 Handwriting Slant Overview

In the SWRS, slant correction is the fundamental part of preprocessing stage. Slant correction is an elementary process for analytical as well as global handwritten character recognition techniques [3]. In analytical recognition technique, segmentation is better achieved by slant correction. In this technique text is divided to its constituent parts. It critically influences recognition precision when it is matched up to single character orientation patterns [4]. The use of slant correction in global recognition technique is matching of input image with lexicon images [4].

Variability of writing styles causes slant in a script word images. Correction of slant can decrease the inconsistency in the contours of these word images. It also helps in the afterward processes such as feature extraction and segmentation.

Slant is defined as, "the angle in clockwise direction which the near-vertical strokes of the handwritten word make with the perpendicular to its baseline" [5].

Fig 2.1 Handwriting slant

Slant can differ significantly between persons. It also diverges within a given script of writing. Various letters in a single word can have inconsistent slants [6]. Presence of slant makes the script processing difficult. To avoid such difficulties, slant correction is employed as amendatory step in preprocessing stage of script recognition system. In the literature generally handwriting slant is divided into two classes [7].

- Positive slant
- Negative slant

Positive Slant

If the stroke of word leans towards the right, then the slant of handwriting is said to be positive.

Fig 2.2: Positive Slant

Negative Slant

The slant of handwriting is considered to be a negative slant if the stroke of word is inclining towards the left.

Fig 2.3 Negative Slant

The slant in any piece of handwriting stroke is measured in angles. There are two ways to measure slant; manual and automatic [8]. Positive slant ranges from 0 to 89 degrees and Negative slant falls in the range of 91 to 180 degrees, but generally the range of positive and negative slant measurement is taken in consideration as under [5]:-

- Positive slant - 60 to 85 degrees
- Negative slant - 95 to 110 degrees

2.2.1 Slant Detection

Slant detection is the appraisal of the angle between the upright direction of the strokes and base line of word [5]. In the literature, several techniques for slant detection have been proposed; a comprehensive description of different techniques is furnished in the next chapter.

2.2.2 Slant Correction

Slant correction is the process, which attempts to normalize the slant of the characters in a line or word to the vertical [9]. Shear transform is used in slant correction process. In matrix form shear transform is an elementary matrix that symbolizes the accumulation of a multiple of column to a row or row to a column.

This transform only corrects the apparent way of the data and leaving the original area unchanged. Geometrical representation of shear transform along x axis and y axis is as follows:

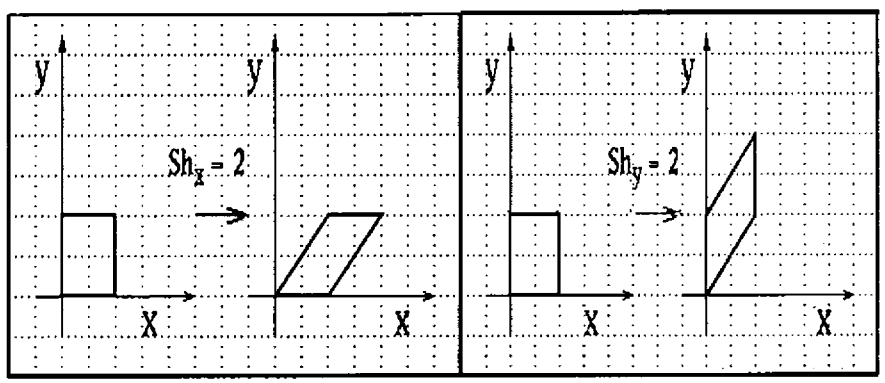


Fig 2.4 [38]: Shear transform along (a) along x- axis (b) along y- axis

In this case all the writing structures are unspoiled and only that pair of points which are in a linear space are taken. These points are separated along the axis containing the shear element in the row matrix and replaced with those pairs whose separation is not along axis but has two vector components. In slant correction, it is convenient to transform the converting definition than all the data points [21].

2.3 The Slant Problems

Transformation of the data in slant correction process makes also changes in other features [22]. Inaccurate slant estimation results into alteration of the data, making the recognition task difficult. Moreover it also consumes time in slant correction process, which could be used for the recognition process in its place. In general, two types of famous problems are defined in a slant correction process [25]:

- Non-slanted Modification
- Improper Slant correction

2.3.1 Non-slanted Modification

In a non-slanted modification, the characters which are upright or near vertical, are cured as slanted character. It affects the projected slant of subsequently unconcerned strokes. Figure 2.3.1 shows an example of non-slanted modification problem.

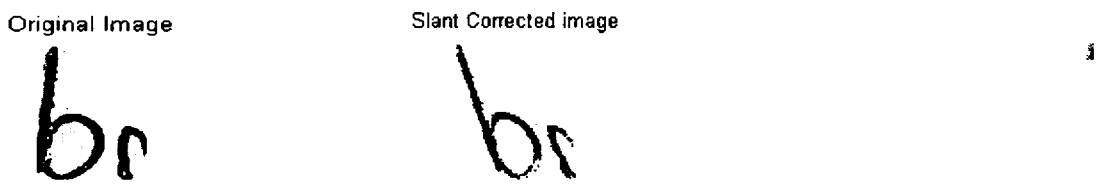


Fig 2.5: (a) Non-slanted image (b) After applying slant correction technique

2.3.2 Improper Slant correction

The improper slant correction causes serious deformation of character, which may results into important information loss [18]. In this problem long strokes with specific slant may be over adjusted or remains under estimate. Fig 2.3.2 shows example of improper slant correction.

Fig 2.6: (a) Original Image (b) Image after applying slant correction technique

2.4 The Slant Applications

In SWRS, slant elimination decreases deviation between different samples of characters enabling credentials of those samples easily. Another important slant correction application is in segregation and recognition steps. It creates the segmentation and recognition task simple because of the distinct nature of vertical shape letters as compared to slanted characters, which enable additional interstellar between vertical shape letters [14]. In addition to this slant correction is an important area in the fields of forensic science in order to improve temperament traits. The cases in which someone strained to cover up himself by writing in an abnormal slant,

he can be identified by correcting disguise writing slant [18]. The process of slant correction works in parallel with other preprocessing steps at the same time. Due to all these applications, in SWRS, slant correction has been recognized as a standard step, ordinarily next step to foreground background separation and after slope correction of word images [14].

CHAPTER 3

Slant Correction Techniques

Several techniques have been developed for the estimation and correction for slant in handwritten word images. A review of different techniques is cited under:

- Projection profile technique (PPT)
- Chain code technique (CCT)
- Zernike moments technique (ZMT)
- Radon transform technique (RTT)
- Non uniform techniques (NUT)
- Propagation map technique (PMT)
- Regression based technique (RBT)
- Cost function technique (CFT)
- Histogram based technique (HBT)

3.1 Projection Profile Technique

In PPT, slant is determined by using the largest stroke of character. For each of the contours, difference is measured and the border connected points of the writing with base line are perceived [29]. The points which are associated to near vertical are treated as vertical stroke. Local slant is estimated for each stroke and the maximum variable projection corresponds to the best position to the text line is taken as a global slant angle. This technique is reasonably fast as compared to the other approaches, but the main drawback of this process is that numerous exploratory limits have to be listed [21].

3.2 Chain Code Technique

A technique for handwriting word slant estimation by using chain code contour processing was described in [34]. The method uses the chain code histogram of whole perimeter pixels. The base line elements are ignored in slant estimator. This method is very simple and effective in the slant range of $\pm 45^{\circ}$ [31].

In [32] the authors proposed local slant function using x-direction. The authors of [32] also describe local slant using following approaches:

- Iterative chain code technique
- High-speed iterative chain code technique
- 8-directional chain code technique

All these techniques perform well as compare to the average slant estimation and correction approaches.

3.3 Zernike Moments Technique

The Zernike moments technique based on the average inclination of the Zernike reconstructed images for low moments [11]. Zernike moments are a sort of orthogonal moments which possess useful rotation invariance properties. Their module has been used to obtain image parameters invariant to rotation. As compared to other techniques, slant is more accurately corrected by this technique. It also slightly increases the processing speed.

3.4 Propagation Map Technique

This technique is based on a combination of projection profile and dynamic programming techniques. A non-uniform slant angle in each column is estimated for each vertical stroke, which results in a slant map [25]. The resulting slant map is modified to avoid false positives. Dynamic programming algorithms are applied to get an optimal smooth solution. This technique is vastly complex and moderately accurate. The disadvantage of this method is that; it fails to correct the connectors in cursive script [25].

3.5 Radon Transforms Technique

Radon transforms technique is based on ramp flow of black and white pixels in the direction of projection. In this technique average angular slant of long vertical stroke is calculated and these long strokes are treated as a measure function of average word slant. As compare to traditional

techniques this algorithm performs well on short words and enhances the recognition accuracy of words [26].

3.6 Non Uniform Techniques

Non-uniform slant correction techniques calculate variable slant angles for each character in a word image and formulate this variable slant angles as a constrained optimization. The optimized problem is solved by applying dynamic programming based algorithm [27]. The difference between local slant removal and conventional slant correction techniques is that the erstwhile depends on global optimization of the sequence of non-uniform slant directions whereas the latter is independent. The recognition accuracy and performance of this technique on word images is better than conventional techniques.

3.7 Regression Based Technique

This technique is based on the maximum correlation between two upright strokes in a word image. In this technique one stroke is moved relatively to the other stroke in accordance with equal character base line levels [33]. First, all the border pixels of image are extracted. Then non zero x direction elements is calculated. The average slope is estimated by non-zero vertical values. The image is rotated about the x- axis, and then a vertical projection histogram for each angle is calculated. From these calculated angles median is taken as the estimated angle and shear transform is applied to correct the slant. This technique performs well on long word images but have problem with short word images.

3.8 Cost Function Technique

CFT estimates slant on the assumption that non existence of slant in a given handwritten word provides superior represent of the slant. A measure function (s) is used to obtain slant absence across the word. The cost function (S) depends on the calculation of upright density histogram of the image [30]. The maximum value of (S) is assumed as estimated slant. After slant estimation shear transform is used to correct the original image. The technique performed well but the disadvantage of this method is that, it is time consuming.

3.9 Histogram Based Technique

Slant correction using histogram based method is presented in [35]. In this paper the author estimates the slant with the perception that a non-slanted text will have a more intense histogram than slanted text. A vertical projection of upright text will have higher peaks and wider troughs than a lower vertical projection of slanted text [30]. In [28] the author measured slant of word image using times signal histogram. Wigner-Ville distribution is applied to estimate its slant angle in the range of $\pm 45^{\circ}$ with respect to its original position. The resulting angle with highest intensity distribution is taken as the measure function. The approach is very simple and performed well but has heuristic parameter to calculate like vertical histogram, Wigner-Ville distribution and shear angle for each character make it time demanding [15].

This thesis presents modified technique for slant correction using 8-DCCT. In addition to this, the relationship between different directions like 4-direction, 8-direction and 12-direction are also discussed. Moreover, a comparative analysis of chain code with histogram based slant

correction techniques, regression based technique and structural feature based technique is also presented in the next section.

CHAPTER 4

SIMULATION RESULTS

It is very difficult to evaluate, investigate and compare the efficiency of different slant correction techniques. Of course, it remains hard to compare different algorithms when they have been designed for and evaluated in different systems. In the literature, efficiency of slant correction techniques were evaluated mostly based on human perceptions which differ from author to author. Moreover, in the literature there is no stand alone procedure for evaluation of slant estimation techniques. Besides, a slant correction system is scarcely ever evaluated independently in the literature, most of the researchers evaluated their preprocessing techniques as an overall system and slant correction techniques are treated as a part of the overall system. In addition to this, the efficiency of slant correction techniques are also described indirectly by taking into account the enhancement it affords to an existing word script recognition system.

The most common way used in the literature to evaluate efficiency of different slant correction techniques as already mentioned is by sight which makes different opinions in the case of words that include characters of dissimilar orientation. The major principle of slant correction techniques is to generate script more convenient for digital processing by a definite system.

Generally the range of positive and negative slant measurement is taken in consideration as under [5]:-

- Positive slant - 60 to 85 degrees
- Negative slant - 95 to 110 degrees

In this work, efficiency of slant correction techniques was implemented in MATLAB. A number of experiments were conducted on test set to evaluate proposed techniques. The test set consisted of 150 words of selected from IAM database. The performance of slant angle estimation and correction techniques is based on manual measured angel in each case. Consequent angle was calculated and stored in each case and formulated into a table. The result of the measured angel is considered true when the measured angel after slant correction occurred in the range 85 to 95 degree. The results of slant estimation and correction using different techniques namely; histogram based method, regression based methods, structural feature based technique, 4-directional chain code methods, 8-directional chain code methods, modified 8-directional chain code methods, 12- directional chain code methods are shown in this chapter. The result table includes the following terms:

- **Angle:** the estimated slant angle.
- **True:** the results which are occurred in the range 85 to 95 degree.
- **False:** the results which are not in the range 85 to 95 degree.
- **Not work:** the image which is not recognized by the algorithm.

This table is used to evaluate the efficiency of different implemented techniques. The percentage of correct results (accuracy), percentage of false results (error) and percentage of not worked (recognition) is described as:

- **% age of Accuracy** = (No. of True Results / Total Images) * 100
- **% age of Error** = (No. False Results / Total Images) * 100
- **% age Recognition** = (No. Unknown Results / Total images) * 100

In conclusion, the proposed/modified slant correction algorithm works rationally well, and it is simple and fast, easier to understand and implement. The application of proposed/modified slant correction method to the above mentioned data produced very satisfactory results. In general, it is clear that even in the hardest cases the produced word is considerably improved as regards its processing in further stages.

4.1 8-Directions Chain Code Technique

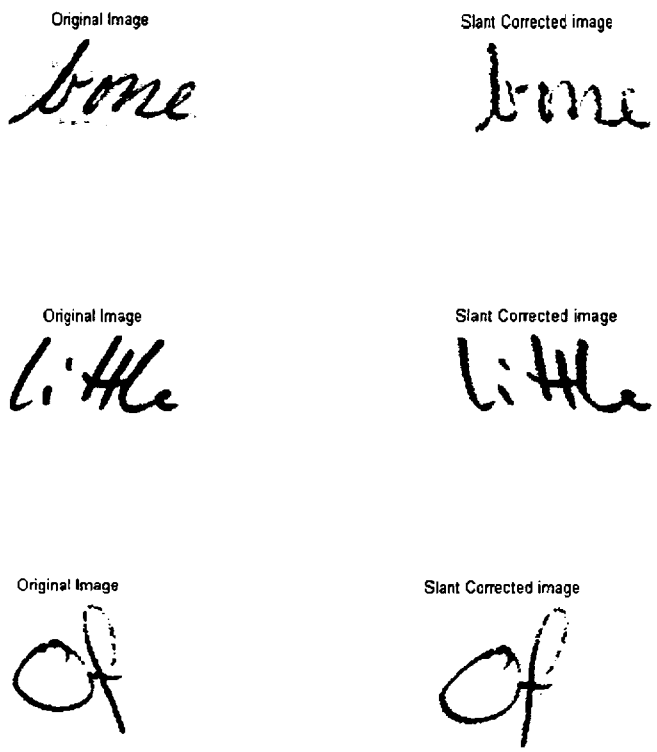
The result of this technique is assessed after performing experiments on a randomly collected data of 150 words images. Total word images of 150 numbers with 2 to 9 charter per word length from different writers were selected. The data used in these experiments was taken from renowned handwritten database: IAM-DB.

The technique used in these experiments was earlier presented by the author [31] and uses following equation to estimate the slant of a word:

$$\theta = \tan^{-1}\left(\frac{(2n_1 + 2n_2 + n_3) - (n_5 + 2n_6 + 2n_7)}{(n_1 + 2n_2 + 2n_3) + 2n_4 + (2n_5 + 2n_6 + n_7)}\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4.1)$$

In this equation, nominator is the difference of positive and negative projection histograms of horizontal directions and denominator is the vertical histogram of all directions except 0 directions.

A number of images after slant correction using this method and the original images are shown in the fig. 4.1. This technique corrects the slant with accuracy of 93.33%. In some cases results are not desirable.



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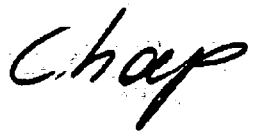
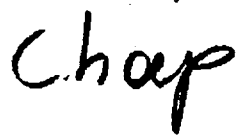


Slant Corrected image



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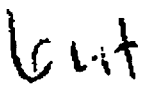

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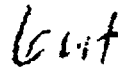


Original Image

Slant Corrected image

Original Image

Slant Corrected image

Original Image

Slant Corrected image

Original Image

Slant Corrected image

Figure 4.1: Slant correction using 8-DCCT (a) Original images (b) Images after slant correction

Table 4.1 shows experimental results of 8-DCCT.This technique correct 144 images out of 150 images with accuracy rate 93.33%, the false images are 10 with error rate 6.67 % and all the images applied to this technique is recognized by 100.00% rate.

Table 4.1: Experimental results of 8-DCCT

Image	Angle	Correct	False	Not work
01	0.0821	1	-	-
02	0.0718	1	-	-
03	0.0788	1	-	-
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
148	0.0746	1	-	-
149	0.0663	1		-
150	0.0727	1	-	-

Total	-	140	10	0
% age	-	93.33	6.67	0.00

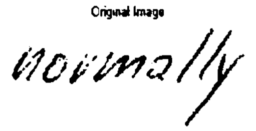
4.2 Modified 8-Direction Chain Code Method

The result of this technique is evaluated after performing experiments on a randomly collected data of 150 words images with length of 2 to 9 letter per word from different writers were selected. The data used in these experiments was taken from renowned handwritten database: IAM-DB.

The enhancement in [31] for slant angle estimator of 8-direction chain code is presented as under.

$$\theta = \tan^{-1}\left(\frac{(2n_2 + n_3) - (n_5 + 2n_6)}{(2n_2 + 2n_3) + 2n_4 + (2n_{5+} 2n_6)}\right) \quad \text{..... (4.4)}$$

In this technique, the range of chain code directions are taken into consideration nears 25° from the horizontal direction with assumption that slant is likely to become oversensitive in these areas and not sensitive enough in the remaining areas. We neglect the near horizontal elements which give better results than the technique described in [31]. The results may be viable due to its approximated nature. After estimating slant angle shear transformation is used to normalize the word image. Fig. 4.2 shows original images and after slant correction images applying enhanced method.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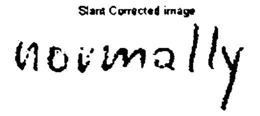
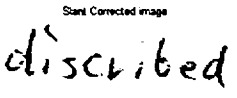

Slant Corrected image


Original Image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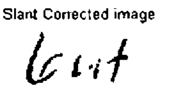
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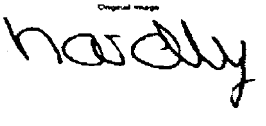
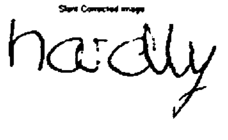
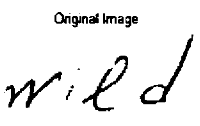





Original Image


Slant Corrected image

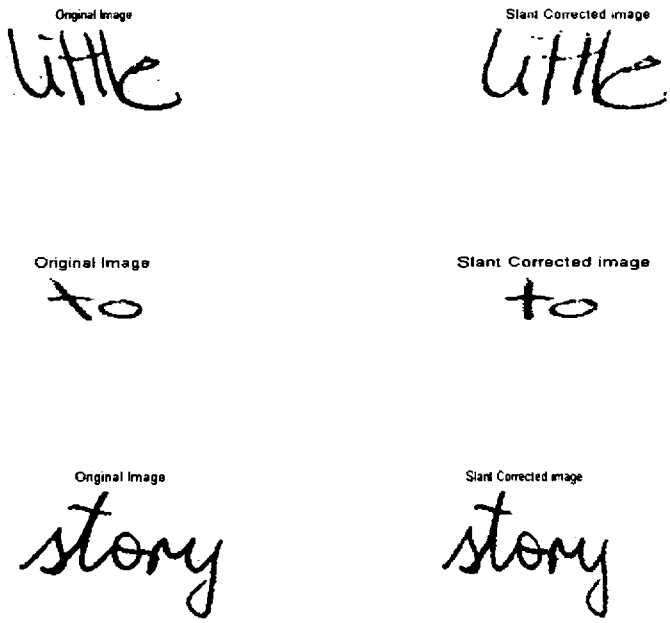


Figure 4.2: Slant correction using modified 8-directional chain cod method

(a) Original images (b) Images after slant correction

Table 4.2 shows experimental results of proposed techniques. This technique slightly enhances the overall experimental result than the technique discussed in section 4.1.This technique correct 144 images out of 150 images with accuracy rate 96.00%, the false images are 3 with error rate 2.00 % and all the images applied to this technique is recognized by 98.00% rate.

Table 4.2: Experimental results of modified 8-DCCT

Image	Angle	Correct	False	Not work
01	0.5124	1	-	-
02	0.1039	1	-	-
03	-0.1532	1	-	-

.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
148	-0.2985	1	-	-
149	0.0433	-	1	-
150	0.08866	-	1	-
Total	-	144	3	3
% age	-	96.00	2.00	2.00

4.3 Histogram Based Method

The result of this technique is deliberated after execution of experiments on the same data set as described in pervious techniques. Total word images of 150 numbers with 2 to 9 charter per word length from different writers were selected. The data used in these experiments was taken from renowned handwritten database: IAM-DB.

The histogram based process discussed in the paper [33] is implemented in this section to analysis its accuracy with directional techniques of section 4.1 & 4.2. The algorithm of paper [33] is given as under:

i. Transform the line along shear angles from -45 to 45.

ii. Calculate a vertical projection histogram for each angle.

iii. Calculate Wigner-Ville distribution of each histogram.

iv. Select angle representing the largest distribution intensity.

v. Choice the consistent results as corrected image.

The results show that corrected images persists well in the range of ±45 degrees. The majority of handwritings slant angle covers maximum of ±45 degrees. Figure 4.3 shows the results for histogram based method.

Figure 4.3: Slant correction using histogram based method (a) Original images (b) Images after slant correction

Table 4.3 shows experimental results of histogram based method. This technique correct 132 images out of 150 images with accuracy rate 88.00%, the false images are 13 with error rate 8.67 % and all the images applied to this technique is recognized by 96.67% rate.

Table 4.3: Experimental results of histogram based method

Image	Angle	Correct	False	Not work
01	1.2723	-	1	-
02	1.3214	1	-	-
03	0.5285	1	-	-
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
148	0.2721	1	-	-
149	1.4144	-	1	-
150	0.5082	1	-	-
Total	-	132	13	5
% age	-	88.33	8.67	3.33

4.4 Regression Based Method

The slant correction using regression based method has been tested on a collection of word images taken from the IAM-DB databases. In more detail, 150 word images with 2 to 9 charter per word length from different writers were selected randomly.

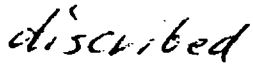
The regression based algorithm for slant estimation and correction for a given word consists of following steps:

1. Extract all the non-zero border pixels of image.
2. Find minima along x and y direction.
3. Calculate slope using equation

$$a = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sum (x_i - \bar{x})^2} \quad \text{......................................} (4.1)$$

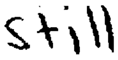
4. Rotated about the x- axis for different angles between 0° and $+180^{\circ}$.
5. Calculate a vertical projection histogram for each angle.
6. Chose median value as slant angle.

It is assumed that the angle gives the image, which has most of the characters in vertical position. The result shows us that the slant correction in this method is more accurate than other method. In Fig.4.4 some image of IAM-DB as inserted in the system and after the slant correction is shown.

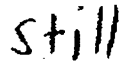


Original Image

Slant Corrected image



Original Image

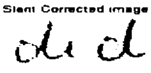


Slant Corrected image

Original Image

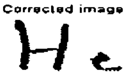
Slant Corrected image

Original Image



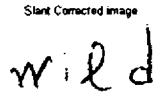
Slant Corrected image

Original Image



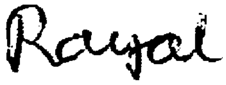
Slant Corrected image

Original Image



Slant Corrected image

Original Image



Slant Corrected image

Figure 4.4: Slant correction using histogram based method (a) Original images (b) Images after slant correction

Table 4.4 shows experimental results of regression based method. This technique correct 140 images out of 150 images with accuracy rate 93.33%, the false images are 3 with error rate 2.00 % and all the images applied to this technique is recognized by 96.33% rate.

Table 4.4: Experimental results of regression based method

Image	Angle	Correct	False	Not work
01	72.68	1	-	-
02	103.35	1	-	-
03	105.93	1	-	-
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
148	68.93	1	-	-

149	-	-	-	1
150	57.83	-	1	-
Total	-	140	3	7
% age	-	93.33	2.00	4.66

4.5 Structural Features Based Method

Slant correction using structural features based method has been tested on a collection of word images taken from the IAM-DB databases. In more detail, 150 word images with 2 to 9 charter per word length from different writers were selected randomly.

The structural features based algorithm for slant estimation and correction for a given word is described as under [35]:

Convert given image into binary image say B(r, c), where r is the height and c is the width of image.

1. Set $B_1(i, j) = \{ B(i, j) \mid (i, j) = 1\}$, where $B_1(i, j)$ is the left most pixel of the image.
2. Find maxima as $B_2(x, y) = \text{Max } B_1(i, j)$, where $B_2(x, y)$ is the first from the left most pixel of the image.
3. Set $B_3 = (i, y)$
4. Calculate distance using equation

$$\|d_1\| = \sqrt{(i-j)^2 + (i-j)^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4.1)$$

&

$$\|d_2\| = \sqrt{(i-j)^2 + (i-j)^2} \quad \text{.....(4.2)}$$

5. Calculate slope using equation

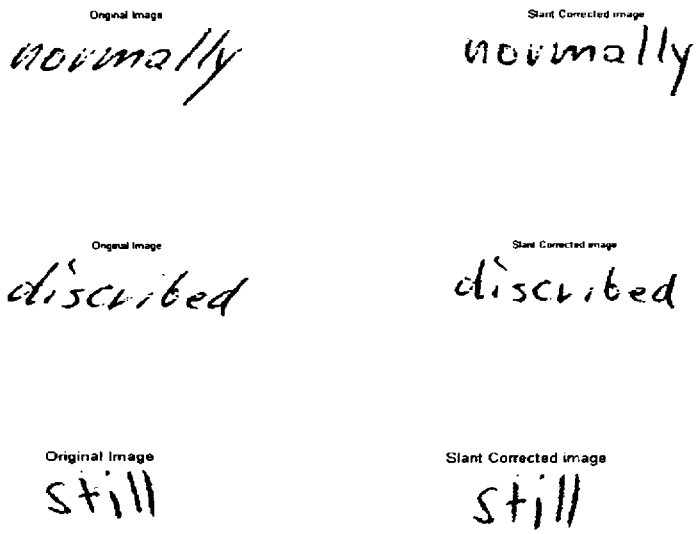
$$s = \left[\frac{(j-y)}{(i-x)} \right] \quad \text{..... (4.1)}$$

If s < 0 then k = -1 else k =1 where k is shear direction

6. Calculate slant angle using equation

$$\theta = k * \sin^{-1}\left(\frac{d_2}{d_1}\right) \quad \text{..... (4.1)}$$

In Fig.4.5 some image of IAM-DB as inserted in the system and after the slant correction is shown.



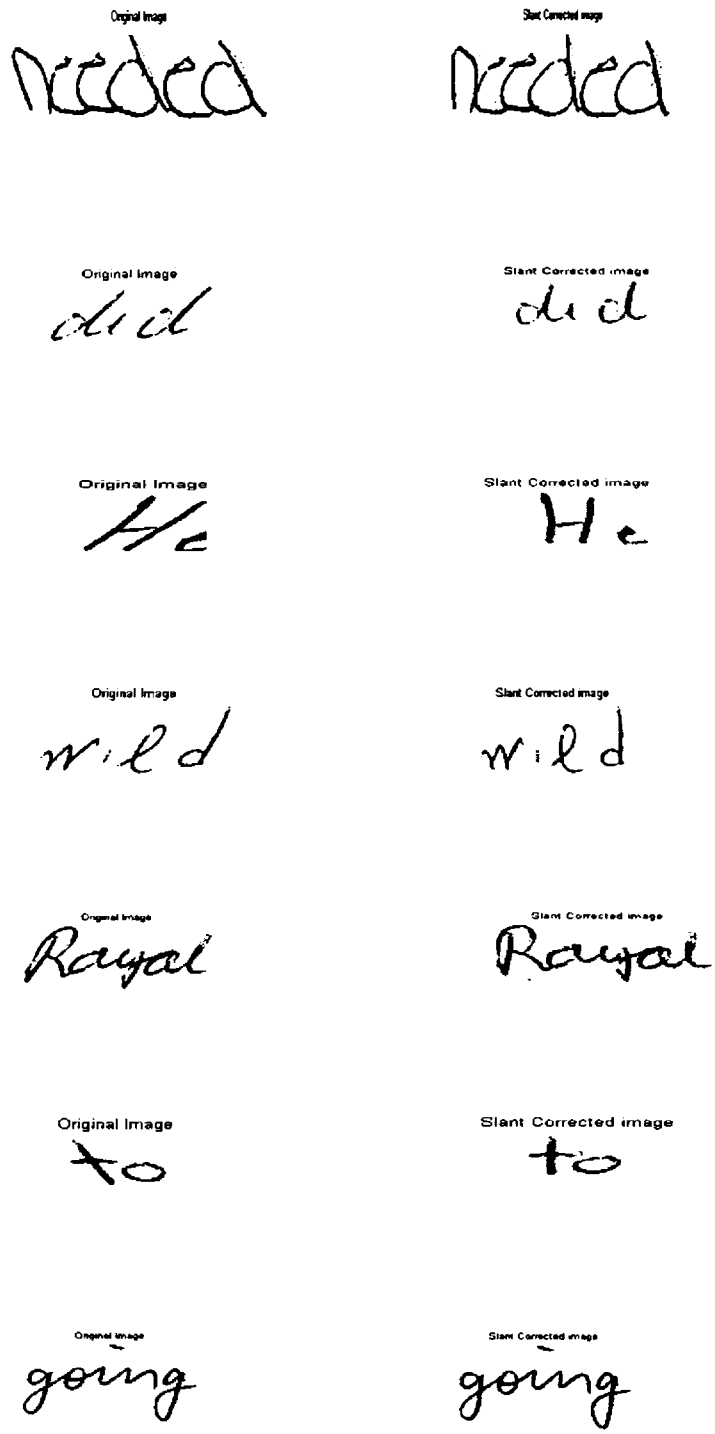


Figure 4.5: Slant correction using Structural features based method (a) Original images (b) Images after slant correction

Table 4.5 shows experimental results of structural features based method. This technique correct 138 images out of 150 images with accuracy rate 92.00%, the false images are 8 with error rate 5.33 % and all the images applied to this technique is recognized by 97.33% rate.

Table 4.5: Experimental results of structural features based method

Image	Angle	Correct	False	Not work
01	72.68	1	-	-
02	103.35	1	-	-
03	105.93	1	-	-
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
148	68.93	1	-	-
149	-	-	-	1
150	57.83	-	1	-
Total	-	138	8	4
% age	-	92.00	5.33	2.64

4.6 4-Directions Chain Code Technique

The result of this technique is assessed after performing experiments on a randomly collected data of 150 words images. Total word images of 150 numbers with 2 to 9 charter per word length

from different writers were selected. The data used in these experiments was taken from renowned handwritten database: IAM-DB.

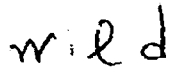
In this technique slant estimation is implemented using the average slant estimator as described in [7]:

$$\theta = \tan^{-1}\left[\frac{n_1 + n_2 + n_3}{n_1 - n_3}\right] \quad \text{..... (4.4)}$$

Figure 4.6 shows the results for this technique. This technique performs well within the limit of slant angle less than 45°.

Original Image

Slant Corrected image

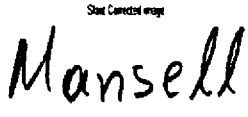


Original Image

Slant Corrected image

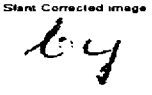
Original Image

Slant Corrected image

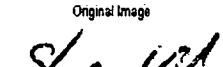


Original Image

Slant Corrected image



Original Image



Slant Corrected image

Original Image

Slant Corrected image

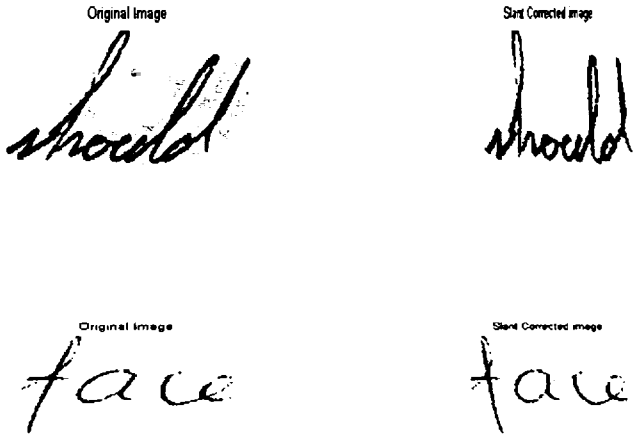


Figure 4.6: Slant correction using 4-DCCT (a) Original images (b) Images after slant correction

The implementation results of 4-DCCT are shown in table 4.6. This technique correct 107 images out of 150 images with accuracy rate 71.33%, the false images are 42 with error rate 28.00 % and all the images applied to this technique is recognized by 99.33% rate.

Table 4.6: Experimental results of 4-DCCT

Image	Angle	Correct	False	Not work
01	0.0274	1	-	-
02	0.0405	1	-	-
03	0.0308	1	-	-
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.

148	0.487	1	-	-
149	0.250	-	1	-
150	0.3350	-	1	-
Total	-	107	42	1
% age	-	71.33	28.00	0.67

4.7 12-Directions Chain Code Technique

The result of this technique is assessed after performing experiments on a randomly collected data of 150 words images. Total word images of 150 numbers with 2 to 9 charter per word length from different writers were selected. The data used in these experiments was taken from renowned handwritten database: IAM-DB.

The slant estimator of the 12-DCCT is given by [14]

$$\theta=\tan^{-1}\left(\frac{(3n_1+3n_2+3n_3+2n_4+n_5)-(n_7+2n_8+3n_9+3n_{10}+3n_{11})}{(n_1+2n_2+3n_3+3n_4+3n_5)+3n_6+(3n_7+3n_8+3n_9+2n_{10}+n_{11})}\right) \quad \text{..... (4.5)}$$

In equation 4.5, nominator is the difference of positive and negative projection histograms of horizontal directions and denominator is the vertical histogram of all directions except 0 directions.

Figure 4.7 shows the results for 12-DCCT.


Original Image
Slant Corrected image
Original Image
Slant Corrected image
Original Image
Slant Corrected image
Original Image
Slant Corrected image
Original Image
Slant Corrected image
Original Image
Slant Corrected image
Original Image
Slant Corrected image

Figure 4.7: Slant correction using 12-DCCT (a) Original images (b) Images after slant correction

The experimental results of 12-DCCT are shown in table 4.7. This technique correct 105 images out of 150 images with accuracy rate 70.00%, the false images are 30 with error rate 30.00 % and all the images applied to this technique is recognized by 100% rate.

Table 4.7: Experimental results of 12-DCCT

Image	Angle	Correct	False	Not work
01	0.1802	1	-	-
02	0.1690	1	-	-
03	0.1419	1	-	-
.	.	.	.	.
.	.	.	.	.

.	.	.	.	.
148	0.1576	1	-	-
149	0.1244	-	1	-
150	0.1533	1	-	-
Total	-	105	45	
% age	-	70.00	30.00	-

4.8 Comparison of Different Techniques

Correction of slant using 8-DCCT and proposed technique is presented in this section. A relation between different DCCT is also presented. Moreover, comparative analysis of different slant correction approaches like; chain code method and histogram based are also discussed in this section. It is very difficult to evaluate a slant removal process because the choice of the most suitable result very often falls under human eyes judgment, as there is no hard rule to compare different slant correction approaches described in literature. The application of modify 8-DCCTto the test data set furnished precise results. These techniques provide considerably improved results even in the hardest cases which may helpful for further processing steps.

Fig.4.8 shows result of the 4- DCCT, 8–DCCT, modified 8–DCCT, 12–DCCT, and structural feature based technique, regression based technique and histogram based method applied on two selected word images with positive and negative slant. This result shows that there are no significant difference in the estimation accuracy and the linearity of all these algorithms. In fig 4.9 (a) is the original images, (b) is the slant corrected images after applying modified 8-DCCT,

(c) is the slant corrected images after applying histogram based technique, (d) is the slant corrected images after applying regression based technique, (e) is the slant corrected images after applying structural feature based methods, (f) is the slant corrected images after applying 8-DCCT, (g) is the slant corrected images after applying 4-DCCT, and (h) is the slant corrected images after applying 12-DCCT. The results shows that slant corrected images by modified 8-DCCT method are better than other techniques with an accuracy rate of 96.00%.

a.

b.

c.

d.

Figure 4.9: Slant correction using different techniques(a) original images, (b) images after applying modified 8-DCCT, (c) images after applying histogram based technique; (d) images after applying regression based technique, (e) images after applying structural features based technique, (f) images after applying 4-DCCT, (g) images after applying 8-DCCT, (h) images after applying 12-DCCT.

CHAPTER 5

CONCLUSION AND FUTURE RESEARCH

In handwritten word recognition system slant correction is considered as a standard step for both holistic and analytical approaches. When slants are carefully estimated and corrected, it may make the segmentation simple. It also increases the accuracy of recognition. The research work aims to enhanced efficiency of slant correction technique of script word. The author also presents comparative analysis and evaluation of slant estimation and correction of DCC techniques and histogram based technique.

5.1 Conclusion

Handwritten words slant correction using modified 8-DCCT is discussed in this research work. To estimate and correct hand writing word, slant efficiency evaluation and relationship between different directions are also described. An experimental study of between histogram based technique and chain code technique are also presented in this thesis.

The obtained results are acceptable in each case. The resultant slant corrected images are better than the original image. All these techniques generate results on word level and achieved a recognition rate of greater than 70.0% by using a model data of size 150 words images. The

results after comparison revealed that the proposed method has greatest success rate 96.00% with 98.00% recognition rate. The success rate of this technique is slightly superior to the 8-DCCT, which shows a success rate of 93.33% with 100% recognition rate. The success rate of histogram based technique, structural feature based technique, regression based technique, 4-DCCT and 12-DCCT was noted as 93.33%, 92.00%, 88.00 %, 71.33% and 72.00 % respectively.

5.2 Future Research

Application of modified 8-DCCT on handwritten word segmentation and recognition remains as future research work. In addition to this application, accuracy improvement of text line by this technique and additional comparison studies involving bulky image data and new slant correction techniques will be discussed in future.

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